Original Article

Dental Caries Risk Assessment in Primary School Children Aged 11 to 12 years: Case of Nyarugenge District, Rwanda

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Abstract

Background
Dental caries in children is a public health concern affecting 60-90% of children worldwide. Dental caries perturbs children's eating ability, school performance as well as overall quality of life. This study aimed to determine the prevalence of dental caries and its risk factors among children aged 11 to 12 years in Nyarugenge District in Kigali, Rwanda.

Methods
The cross-sectional analytical study design involved 400 children from Nyarugenge district. By stratified sampling, we selected Gitega and Butamwa primary schools and used systematic sampling to choose the pupils into the sample. An interview and oral examination were performed. Descriptive statistics and logistic regression were done.

Results
Dental caries was observed in 25.5% of children. Deep pits and fissures carried a two-fold risk of getting dental caries than children without deep pits and fissures (OR = 2.4, 95% CI = [1.5; 4.0], P-value < 0.001). Dental plaque was identified as a risk factor for getting dental caries (OR=2.2, 95% CI = [1.2; 3.3], P-value: 0.01).

Conclusion
Dental caries is a public health concern associated with poor oral hygiene, deep pit, and fissures among children aged 11 to 12 years old. Oral hygiene education, application of ART, and regular screening programs are in need.

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Keywords: Prevalence, Dental caries, Children

Introduction

Dental caries in children is a widespread public health challenge, and it is the most prevalent non communicable disease affecting 60%-90% of school children worldwide.[1] Dental caries result from a complex phenomenon characterized by the interaction between bacteria within dental plaque adherent to the mineralized tooth surface.[2]

Mineral loss from the tooth is due to acid created within the adherent dental plaque by bacteria such as streptococcus mutans and lactobacillus leading to weakening of the tooth structure and eventual cavity formation due to masticatory forces.[2] It is a main cause of premature tooth loss in children, contributing to dental pain, orofacial infections, perturbation of children's feeding practices, school absenteeism, poor oral health and quality of life.[4]

The process of dental caries is highly dependent on individual risks factors such as dietary habits, poor or inadequate oral hygiene practices, acidogenicity of plaque bacteria, and access to and use of fluoride-containing dentifrices which impact the mineral deposition on tooth surfaces and acidogenicity of dental plaque.[5] Frequent use of carbohydrates in children has been documented as a risk factor and is associated with parents' educational level, socio-economic status, and oral hygiene practices.[2,5]

Amongst emerging economies in Asia the prevalence of untreated dental caries and its sequelae has been reported to range between 53.3% in Malaysia [6] and 85% in China.[7] These untreated dental caries have been associated with poor oral hygiene, frequent snacking habits and lack of dental visits.[8–10] Disparities in distribution of dental caries in children have been also observed in African countries. A systematic study conducted in African countries, the prevalence of dental caries was between 17.2% and 88.8% and it was associated with lack of access to dental services, low socio-economic status, high frequency uses of carbohydrates, and poor oral hygiene. [8,9] In the East African region, the reported prevalence ranges from 78% in Eritrea,[4] to 57.3% in Uganda.[4]In Rwanda, the national oral health survey reported that 64.9% in the population had dental caries experience and 54.3% were untreated.[11]

A high prevalence of dental caries is reported in children from low income households and rural areas, and it has been attributed to lack of prevention measures and access to dental care services.[2,12,13] Female children were more affected by dental caries.[7,14,15] On the contrary, in developed countries, dental caries have declined in children due to regular screening, improvement of oral hygiene practices, increased use of dental sealants, tooth brushing with toothpaste and use of fluoridated water.[16] It is important to recognise that dental caries cannot be managed by restoration alone.[17]

Early detection of dental caries has benefits such as preservation of natural dentition, reduced chances of progression of dental caries to deeper carious lesions and cost involved.[18–20] Dental caries risk assessment is used to predict future occurrence of the condition based on the distribution of the associated risk factors. The approach has been proven to be efficient in prevention and control of dental caries regardless of the resource limitations.[19] The approach emphasizes on identification of factors predisposing an individual to dental caries rather than focussing on dental caries itself.[17]

With the understanding of the relationship between caries risk factors, diseases indicators and protective factors of dental caries, preventives measures can be taken instead of focussing only on treating the disease. The identification of the children's likelihood of getting new carious lesions is based on having one or more caries risk indicators including past caries experience in deciduous dentition or in permanent dentition, frequent ingestion of carbohydrates food, white spots, enamel defect or restoration placed within range of three years.[3,8] On the other hand, dental caries protective factors such as the use of oral mouth wash, appropriate oral hygiene practice, use of fluoridated tooth paste, or access to water community fluoridation are therapeutic factors that help to correct the pathological condition of dental caries. [20,22,23]

Currently, in most African countries including Rwanda, dental caries is still managed mainly by extraction of teeth, and prescription of antibiotics and painkillers. [22] However, extraction does not stop further progression of new dental carious lesions. Research shows that people who experienced dental caries in the past are at high risk of getting new dental caries' lesions and there is high probability of pulp involvement once dental caries developed at early age.[23]

The main objective of this study was to determine the prevalence of dental caries and associated caries risk factors in primary school going children aged 11 to 12 years old within Nyarugenge District, Kigali, Rwanda.

Methods

Study design and Setting

A quantitative descriptive and analytical cross-sectional study was conducted in Gitega and Butamwa primary schools of Nyarugenge district, from October 2017 to January 2018. According to the Rwanda fourth Population and Housing Census of 2012, Nyarugenge is one of the four districts that form the City of Kigali.[24] A little over one quarter (25.1%) of the total population of the City of Kigali reside in Nyarugenge district.[24]

Study population and sample size

Children registered in the Primary School Classes 5 and Class 6 and aged 11 to 12 years were the population of interest. This age was principally important as it is likely that the permanent teeth have erupted except the third molars, and it is the last age group at which a reliable sample may be obtained easily through the primary school system. In addition, the age group is recommended by WHO as a global indicator for international comparisons and surveillance of oral diseases trends.[25] A total of 400 school children aged 11 to 12 years old were recruited and participated in the study. Sample size was calculated using single population proportion Yamane formula with an assumption of 95% confidence level and 5% of degree of precision as cited by Chanuan.[26]

Sampling strategy

Nyarugenge District was chosen based on convenience in terms of affordability and manageability dimensions. A stratified sampling strategy was used to select two primary schools representing urban and rural areas. Sample size was allocated proportionately based on the number of children in each selected school.

With the class name rosters, a systematic sampling was used to select 400 children whose parents or guardian had consented to their participation in the study were selected. The Response rate was 100% due to the use of face to face questionnaire-based interview approach, followed by oral examination.

Data collection Instrument

A questionnaire adapted from a previous study was used,[17] after it had been translated into Kinyarwanda and Back-translated to ensure the quality of translation. Demographic variables including age, gender, resident, socioeconomic status of parents, and parent's education level were recorded. Known dental caries risk factors such as high frequent consumption of sugary food or drinks, dental plaque, access to dental services, deep pit and fissures on teeth, gum recession and condition that affect enamel were also recorded. Decayed and restored teeth were also noted. Children were assigned into dental caries risk categories of low and high risk based on presence of dental caries indicators.

For the physical examination, instruments such as disposable tongue depressor, masks, gloves, and headlamps were used during clinical examination. The presence of dental plaque was examined and recorded using plaque index score as developed and recommended by Silness and Loe.[27] Dental caries was assessed as recommended by WHO for performing oral health survey.[28] Any visible tooth decay or decalcification, any enamel defects, pit and fissure depth, restorations placed within the past 3 years or less, and sealant placed on teeth were examined.[28]

Data collection procedure

The questionnaire-based interview and oral examination were conducted in class by one examiner, and one recording assistant both of whom were trained during the pilot study of 10% of the participants. The recording assistant was seated close enough to the examiner for instructions and codes to be easily heard, and to ensure the examiner

saw if the findings were being recorded correctly. Double data entry was used to ensure the fidelity of the data. Then data validation was done by comparing the values entered for each variable. Any mismatch was crosschecked in the original data form and errors were corrected. All information regarding study participants was kept securely, and identities of the participants were treated confidentially known only to authorized persons. The paper-based questionnaires were kept in locked cupboards, and the study database was stored on Google drive.

Data analysis

Data was entered in Microsoft Excel spread sheet then imported into Stata software version 16 which was used for data storage, querying for monitoring, and formatting for statistical analysis. Descriptive statistical analysis was done to produce frequency tables containing summarized data. Bivariate analysis was performed, and Chi-square statistical test was used to test the associations between risk factors and dental caries. Multiple logistic regression analyses were performed to assess the statistical significance of risk factors to dental caries. The statistical significance level was set at < 0.05. The odds ratios were presented with 95% confidence intervals and P value. Statistical analysis commands were saved as do-file for archiving purpose and for future use.

Ethical clearance

Ethical clearance with approval notice No 333/CMHS IRB/2017 was obtained from Institutional Review Board of the University of Rwanda, College of Medicine and Health Sciences (IRB/UR-CMHS), to conduct this study. Permissions from Nyarugenge District and head teachers was obtained prior to the beginning of data collection. The information sheet and consent form were translated to Kinyarwanda and sent with the children to the parents or guardians. Signed consent form the parent was returned by the children prior to the beginning of data collection. The teachers signed consent on behalf of the parents without formal education. Children whose parents did not give consent were excluded from the study. In addition to consent forms, the children signed assent form to participate to ensure that participation in this study was voluntary. There were no risks for participating in this study.

Results

Socio-demographic characteristics of study participants

A total of 400 primary school children aged 11 to 12 years old of Nyarugenge District were examined. Table 1 shows that 52% and 48% were boys and girls respectively. Most (93.5%) of the children had parents or guardians with primary or no formal educational level, and 6.5% had secondary or higher education level. The majority (68%) of the children were from low-income families (Social category 2 or below). Children from high income families in category 3 or higher were 32%. Most participants (54%) resided in the rural area, and the rest (46%) in the urban area.

Table 1. Socio-demographic characteristics of respondents

Variables	Frequency (n)	Percentage (%)
Gender		
Male	208	52
Female	192	48
Parent's educational level		
Primary education or less	374	93.5
Secondary education or above	26	6.5
Parent social category		
Category 2 and below	272	68
Category 3 and higher	128	32
Residence		
Urban	185	46
Rural	215	54

Dental caries risk factors distribution among study participants

Table 2 shows that 25.5% of study participants had dental caries and 4% had restorations (filling) of the teeth within the past three years. High frequency consumption of sweetened foods or beverages of more than 3 times per day was reported in 38.3% of study participants. The proportion of participants who had visible dental plaques on teeth were 63.5%, deep pit and fissure 37.3%, gum recession 3%, systematic condition that affect teeth were 10%. The study participants who reported to use fluoridated toothpaste were 87%. The reported frequency of tooth brushing once a day was 71% and twice or more was 29%. Few (2%) participants had dental sealants.

Table 2. Descriptive statistics of the study sample (N = 400)

Variables	Frequency (n)	Percentage (%)
Dental caries		
Yes	102	25.5
No	298	74.5
Filling component		
Yes	16	4
No	384	96
Sugars intake >3 times per day		
Yes	153	38.5
No	247	61.5
Visible dental plaque		
Yes	254	63.5
No	146	36.5
Deep pit and fissure on teeth		
Yes	149	37.3
No	251	62.7
Gum recession		
Yes	13	3
No	387	97
Systemic condition affects teeth		
Yes	41	10
No	359	90
Use of fluoridated toothpaste		
Yes	347	86.8
No	53	13.2
Teeth brushed twice a day		
Yes	117	29
No	283	71
Access to dental services		
Yes	146	37
No	254	63

Dental caries risk factors

Table 3 shows the distribution of study participants by dental caries risk factors. Chi square statistically significant results of association between the assessed factors and dental caries were found among participants who had dental plaque on teeth (P = 0.002, deep pit and fissure (P < 0.001), other systemic conditions that affect teeth (P < 0.001), access to dental services (P = 0.02), gum recession (P < 0.001), and residence of study participants (P = 0.01).

Table 3. Characteristics of study sample by dental caries (N = 400)

Variables	Dental Caries			
	Yes	**No**	**Total**	**P-value[a]**
	n (%)	n (%)	n (%)	
Sugars intake >3 times day				
Yes	45 (11.3)	108 (27)	153 (38.2)	0.158
No	57 (14.2)	190 (47.5)	247 (61.7)	
Dental plaque on teeth				
Yes	78 (19.5)	176 (44)	254 (63.5)	**0.002**
No	24 (6)	122 (30.5)	146 (36.5)	
Deep pit and fissure				
Yes	55 (13.7)	94 (23.5)	149 (37.2)	**0.001**
No	47 (11.8)	204 (51)	62 (75)	
Parent's educational level				
Primary and below	93 (23.2)	281 (70.3)	374 (93.5)	0.27
Secondary and above	9 (2.3)	17 (4.2)	26 (6.5)	
Parent's social category				
Category 2 and below	69 (17.2)	203 (50.8)	272 (68)	0.9
Category 3and above	33 (8.2)	95 (23.8)	128 (32)	
Access to dental services				
Yes	47 (11.75)	99 (24.8)	146 (36.5)	**0.02**
No	55 (13.75)	199 (49.8)	254 (63.5)	
Gender				
Male	52 (13)	156 (39)	208 (52)	**0.005**
Female	50 (12.5)	142 (35.5)	192 (48)	
Residence				
Urban	36 (9)	149 (37.2)	185 (46.2)	
Rural	66 (16.5)	149 (37.2)	215 (53.7)	

aBold p values are statistically significant at p<0.05.

Through multiple logistic regressions, the factors that were more likely to be associated with the occurrence of dental caries were deep pit and fissure (OR 2.4, 95% CI: 1.5-3.9, P < 0.001). The presence of visible dental plaque (OR 2.06, 95% CI: 1.2-3.3, P = 0.012), other systemic condition that affect teeth (OR 3.1, 95% CI: 1.6-6.2, P = 0.001) and teeth recession (OR 3.6, 95% CI: 1.1-11.9, P = 0.032).

Table 4. Logistic regression for dental caries risk factors and dental caries (N = 400)

Variables	Full model		Reduced model	
	OR [95% CI]	p-value	OR [95% CI]	P value*
Visible dental plaque				
No	1		1	
Yes	2.2 [1.2, 3.8]	**0.005**	1.9[1.1, 3.3]	**0.01**
Deep pit and fissure				
No	1		1	
Yes	2.4 [1.5, 4.0]	**0.001**	2.3 [1.4, 3.8]	**0.001**
Systemic condition affects teeth				
No	1		1	
Yes	2.7 [1.6, 5.6]	**0.007**	3.8 [1.5, 6.2]	**0.002**
Residence				
Urban	1		1	
Rural	0.5 [0.3, 0.9]	**0.021**	0.6 [0.3, 0.9]	**0.046**
Parent's educational level				
Primary and below	1			
Secondary and above	2.1 [0.8, 5.3]	0.1		
Parent's social category				
Category 2 and below	1			
Category 3 and above	0.8 [0.5, 1.4]	0.5		
Access to dental services				
No	1			
Yes	1.3 [0.8, 2.3]	0.2		
Gender				
Female	1			
Male	0.9 [0.6, 1.6]	0.9		
Sugars intake >3 times per day				
No	1			
Yes	1.5 [0.9, 2.6]	0.08		

Abbreviations: OR , Odds Ratio; CI, Confidence interval. *Bold p values are statistically significant at p<0.05.

Discussion

This study found a prevalence of 25.5% of dental caries among 11 to 12-year-old elementary school pupils. Children with deep pits and fissures had higher risk ratio for dental caries than children with shallow pits and fissures. Despite evidence that dental sealants can aid in preventing tooth decay and its progression, only 1.8% of children had dental sealants. Fifty percent of the pupils were found to be at high risk for developing new carious lesions, indicating a high prevalence. The present results were consistent with other studies conducted in India where 27% of children aged 11 to 12 year old children had dental caries in their permanent [29,30] However, estimate of our study was lower when compared to other studies done in Ethiopia, (49.9%),[31] and other East African nations where pooled prevalence was 45.7%.[4] On other hand, the current estimate of this study was high when compared to another study conducted in a rural area in Tanzania.[32] This may be because children in rural areas consume less refined carbohydrate-containing foods and beverages than their urban counterparts.

Moreover, the comparison of the current results with similar studies done in developed nations reveals that those countries had higher prevalence of dental caries in children aged 11 to 12 years. For instance, in Saudi Arabia prevalence of dental caries in the 12-year-old children was found to be around 65%, and difference between urban and rural was not significant.[33] Likewise, high prevalence of dental caries, above the global average, was also found among children aged 11 to 12 years, with crude prevalence of 61% in the Islamic Republic of Iran, Jordan, Yemen, the United Arab Emirates, Iraq, Bahrain, and Lebanon.[34] An extremely high prevalence were also observed in some European countries such as Latvia (98.5%),[3] and in Macedonia (63.9%).[35] The difference between the rate found in this study and the rest might be attributed to the abundancy of carbohydrate-rich foods in both urban and rural areas of developed countries, poor oral hygiene and social economical distinctions in developed countries in accessing dental care.[5,33,35]

The current study also demonstrated the significant associated factors for dental caries: presence of deep pit and fissure formations on the teeth had higher odds ratio of development of dental caries. This observation aligns with previous research that highlighted the role of enamel defects in the initiation of dental caries.[35,36] This might be attributed to accumulation of food debris, dental plaque, and bacteria in deep pit and fissures. These deep crevices are often challenging to clean which makes them more highly susceptible to dental caries. On other hand, children who were residing in rural areas were significantly less likely to develop dental caries. The most likely explanation for this is that, unlike in rural areas, in urban setting there is a higher availability, accessibility and consumption by children of processed snacks, sugary drinks and fast foods.[33, 35]

Tooth brushing was found to be insufficient in these children; consequently, as demonstrated in another study,[35] dental plaque accumulation, a sign of poor oral hygiene, was found in 63.5% of the children. Poor oral hygiene encourages the formation of dental plaque, which includes bacteria responsible for tooth demineralization and subsequent development of dental caries. The presence of dental plaque, on the other hand, has the impact of preventing saliva from reaching the surface of the teeth for cleaning and deposition of buffers, as well as a lack of fluoride to remineralize tooth hard tissues.[37,38]

The method for determining dental caries, which relied solely on visual and tactile screening rather than radiographic images, was one of the study's limitations. The prevalence of dental caries was consequently likely be underestimated. In addition, a cross-sectional study design was used to predict the relationship between variables, only the factors believed to predispose to

dental caries were examined to determine their significance in the development of dental caries, while the presence or absence of caries at a particular time point was not observed. Therefore, a cohort study in the investigated age group is needed to determine association of dental caries with the underlying causes of tooth decay. Finally, potential recall bias in the reporting of oral health behaviours and practices were controlled by pre-testing the research instruments. Considering that data collection was restricted only to Nyarugenge District, Kigali, Rwanda, the results do not accurately represent the 11 to 12-year-old of Rwandan primary school pupils. However, these findings may serve as a basis for further research, particularly with school-aged children.

Conclusion

Prevalence of 25.5% for dental caries was found to be a public health issue in school children aged 11 to 12 in Nyarugenge District, Kigali Rwanda. The presence of dental plaque, poor oral hygiene, deep pits and fissures on teeth, and residence in urban were factors associated to dental caries. Despite the efforts made in mobilizing health insurance coverage and access to dental services, more than half of the children were at risk of developing new carious lesions. This necessitates the collaboration of dental and medical professionals to develop integrated care for all and prevention measures such as curriculum-based oral hygiene education, fissure sealant application, and regular screening programs in primary schools.

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Authors' contributions

All authors contributed equally to conceptualization of the study, study design, execution, data collection, analysis, and interpretation of data.

Conflict of interest

All authors declare no conflict of interest and no competing financial interest.

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References

1. Rwenyonyi CM, Muwazi LM, Buwembo W. Assessment of factors associated with dental caries in rural communities in Rakai District , Uganda. *Clin Oral Investig*. 2011;15:75–80.
2. Selwitz RH, Ismail AI PN. Dental caries. *Lancet*. 2007;369:51–9.
3. Maldupa I, Sopule A, Uribe SE, Brinkmane A. Caries Prevalence and Severity for 12-Year-Old Children in Latvia. *Int Dent J*. 2020;71:214–23.
4. Teshome A, Muche A, Girma B. Prevalence of Dental Caries and Associated Factors in East Africa, 2000–2020: Systematic Review and Meta-Analysis. *Front Public Heal*. 2021;9:1–15.
5. Ireland R. Clinical Textbook of Dental Hygiene and Therapy. 2006.
6. Kaur S, Maykanathan D, Lyn NK. Factors associated with dental caries among selected urban school children in Kuala Lumpur , Malaysia. *Arch Orofac Sci*. 2015;10:24–33.
7. Hu J, Jiang W, Lin X, Zhu H, Zhou N, Chen Y, et al. Dental caries status and caries risk factors in students ages 12–14 years in Zhejiang, China. *Med Sci Monit*. 2018;24:3670–8.
8. Moynihan PJ, Kelly SAM. Effect on caries of restricting sugars intake: Systematic review to inform WHO guidelines. *J Dent Res*. 2014;93:8–18.

9. Fernandes IB, Ramos-Jorge J, Coelho VS, Pinto ACS, Pordeus IA, Paiva SM, et al. Association between different stages of dental caries in preschoolers and familial socioeconomic factors. *Braz Oral Res*. 2022;36:1–9.
10. Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: a global public health challenge. *Lancet*. 2019;394:249–60. Available from: http://dx.doi.org/10.1016/S0140-6736(19)31146-8
11. Morgan JP, Isyagi M, Ntaganira J, Gatarayiha A, Sarah E, Roomian TC, et al. Building oral health research infrastructure : the first national oral health survey of Rwanda Building oral health research infrastructure : the first national oral health. *Glob Health Action*. 2018;11.
12. Piovesan Fausto Medeiros Mendes José Leopoldo Ferreira Antunes Thiago Machado Ardenghi C. Inequalities in the distribution of dental caries among 12-year-old Brazilian schoolchildren. *Braz Oral Res*. 2011;25:69–75.
13. Bellotto A, Kassawara C, Pereira E, Cortellazzi KL, Maria G, Ambrosano B, et al. Epidemiological assessment of predictors of caries increment in 7-10-year-olds : a 2-year cohort study. *J Appl Oral Sci*. 2010;18:116–20.
14. Arora B, Khinda VIS, Kallar S, Bajaj N, Brar GS. Prevalence and comparison of dental caries in 12 year old school going children in rural and urban areas of Ferozepur city using sic index. *Dent Oral Craniofac Re*. 2015;1:38–41.
15. Lingstro P, Mannaa A, Carle A. Dental caries and associated factors in mothers and their preschool and school children d A cross- sectional study. *J Dent Sci*. 2013;8:101–8.
16. Tomar SL, Reeves AF. People 2010 Objectives. *Acad Pediatr*. 2010;9:388–95.
17. Young DA, Featherstone JDB. Implementing caries risk assessment and clinical interventions. *Dent. Clin. North Am*. 2010. p. 495–505.
18. John D.B. Featherstone et al. Caries Risk Assessment in Practice for Age 6 Through Adult. *CDA J*. 2007;35.
19. Douglas A. Young and John D. B.Featherstone. Caries management by risk assessment. *Community Dent Oral Epidemiol*. 2013;41:53–63.
20. Lennon Áine M. et al. Clinical Applications and Outcomes of Using Indicators of Risk in Caries Management. *J Dent Educ*. 2011;65:1126–32.
21. Bratthall D. A new and interactive way of illustrating the interaction of factors contributing to the development of dental caries D. *Bratthall, G Hänsel Petersson, JR Stjernswärd*. 2004;1–51.
22. Mukashyaka C, Uzabakiriho B, Amoroso CL, Mpunga T, Odhiambo J, Mukashema P, et al. Dental caries management at a rural district hospital in northern Rwanda: a neglected disease. *Public Heal action*. 2015;I:158–61.
23. Young DA, Featherstone JDB. Caries management by risk assessment. *Community Dent Oral Epidemiol*. 2013;41:53–63.
24. National Institute of Statistics of Rwanda (NISR) M of F and EP (MINECOFIN) [Rwanda]. Fourth Rwanda Population and Housing Census. *Fourth Rwanda Popul Hous Census*. 2012;171.
25. Mitiche A, Ayed I Ben. Basic methods. *Springer Top Signal Process*. 2011;5:33–58.
26. Uakarn C. Sample size estimation using Yamane and Cochran and Krejcie and Morgan and Green formulas and Cohen statistical power analysis by G*power and comparisons. *Apheit Int J*. 2021;10:76–88.
27. Feier I, Onisei D, Onisei D. the Plurivalence of the Interpretation of Correlation Between Plaque Score and Bleeding Score. *J Rom Med Dent*. 2009;13:45–8.
28. WHO. Oral health surveys: basic methods. *who*. 2013.
29. Reddy K, Reddy S, Ravindhar P, Balaji K, Reddy H, Reddy A. Prevalence of dental caries among 6–12 years school children of Mahbubnagar District, Telangana State, India: A cross-sectional study. *Indian J Dent Sci*. 2017;9:1.

30. Gupta P, Gupta N, Singh HP. Prevalence of Dental Caries in relation to Body Mass Index, Daily Sugar Intake, and Oral Hygiene Status in 12-Year-Old School Children in Mathura City: A Pilot Study. *Int J Pediatr*. 2014;2014:1–5.
31. Shitie A, Addis R, Tilahun A, Negash W. Prevalence of Dental Caries and Its Associated Factors among Primary School Children in Ethiopia. *Int J Dent*. 2021;2021.
32. Zumpe L, Bensel T, Wienke A, Mtaya-Mlangwa M, Hey J. The oral health situation of 12-year-old school children in the rural region of ilembula in Southwestern Tanzania: A cross-sectional study. *Int J Environ Res Public Health*. 2021;18.
33. Al-rafee MA, Alshammery AR, Alrumikan AS. A Comparison of Dental Caries in Urban and Rural Children of the Riyadh Region of Saudi Arabia. *Front Public Heal*. 2019;7:1–6.
34. Kale S, Kakodkar P, Shetiya S, Abdulkader R. Prevalence of dental caries among children aged 5 – 15 years from 9 countries in the Eastern Mediterranean Region : a meta-analysis. *East Mediterr Heal J*. 2020;26:726–35.
35. Nonkulovska V. Dental Caries Experience of 12-Year-Old Children from Resen Municipality. *Int J Clin Stud Med Case Reports*. 2022;16:1–5.
36. Schwendicke F, Dörfer CE, Schlattmann P, Page LF, Thomson WM, Paris S. Socioeconomic inequality and caries: A systematic review and meta-analysis. *J Dent Res*. 2015;94:10–8.
37. Xu Y, You Y, Yi L, Wu X, Zhao Y, Yu J, et al. Dental plaque-inspired versatile nanosystem for caries prevention and tooth restoration. *Bioact Mater*. 2023;20:418–33. Available from: https://doi.org/10.1016/j.bioactmat.2022.06.010
38. Bashirian S, Shirahmadi S, Seyedzadeh-Sabounchi S, Soltanian AR, Karimi-shahanjarini A, Vahdatinia F. Association of caries experience and dental plaque with sociodemographic characteristics in elementary school-aged children: A cross-sectional study. *BMC Oral Health*. 2018;18:1–12.